April 2, 1940. H. E. HOLLMANN 2,195,456

ELECTRON DEVICE

Filed April 27, 1937

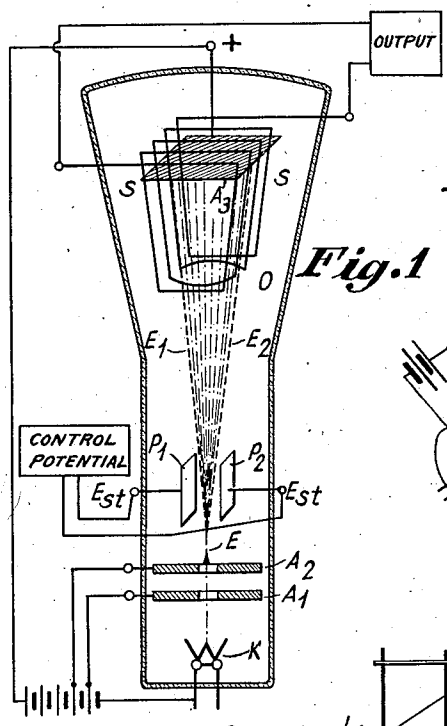


Fig. 1

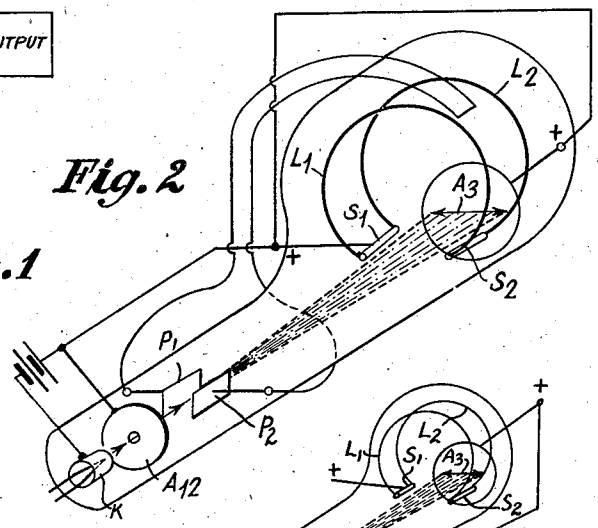


Fig. 2

Fig. 7

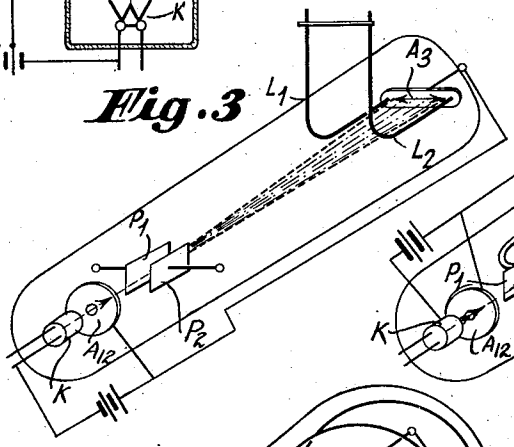


Fig. 3

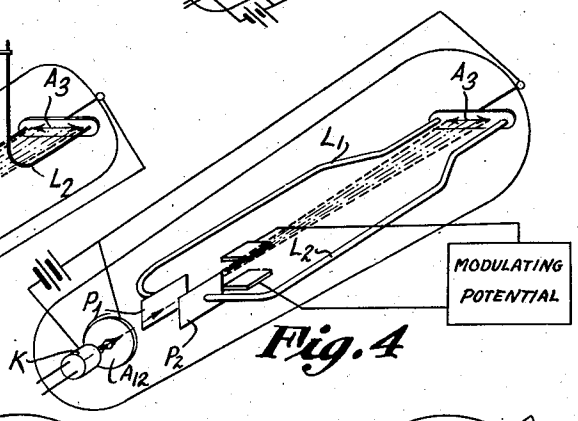


Fig. 4

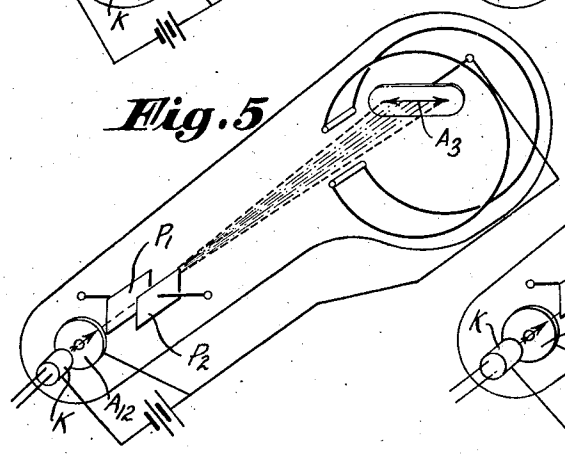


Fig. 5

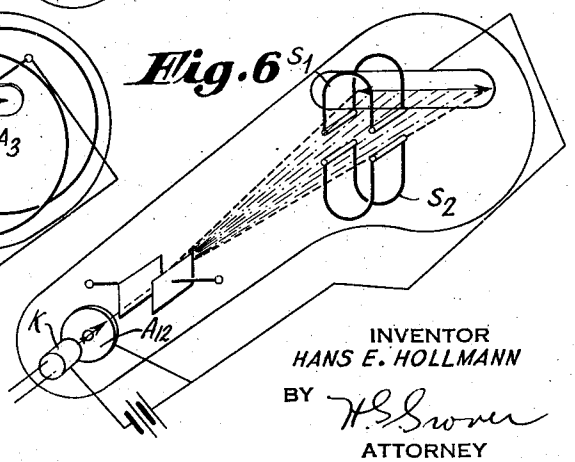


Fig. 6

INVENTOR
HANS E. HOLLMANN
BY H. E. Hollmann
ATTORNEY

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ELECTRON DEVICE

Hans E. Hollmann, Berlin, Germany, assignor to Telefunken Gesellschaft für Drahtlose Telegraphie m. b. H., Berlin, Germany, a corporation of Germany

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12 Claims. (Cl. 250—36)

This invention relates to electron devices and in particular to electronic oscillators in which transversal oscillation energy of the electrons is separated from the kinetic motion energy to produce induction currents in contradistinction to convection or displacement currents.

This invention is related to and is an improvement of my copending application Serial No. 127,343, filed February 24, 1937, and entitled "Electronic systems".

A number of suggestions have been disclosed in the recent art of amplification, generation and frequency multiplication of electrical oscillations to abandon the principle incorporated in the standard electronic tubes, namely, what has been called longitudinal space-charge control by the aid of a control grid interposed in the discharge path or by the aid of a magnetic field acting, as it were, as an "immaterialized" (non-physical) electrode, in order to obviate the failure of these control methods which become more and more evident in proportion as the rate of variation of the control actions comes closer to the velocity of the electronic motions, and thereby solve all of the difficulties and drawbacks associated therewith. Fundamentally speaking, to replace the longitudinal-control principle there is available the transversal control action adapted to be brought upon a filamentary, ribbon or disk-shaped electron jet or pencil. The latter, by ways and means known from the oscillograph art, is deflected out of its original direction by the voltage of current to be controlled, by electrostatic or electromagnetic means, and thus caused to experience transversal oscillations. Where the electrostatic control action is used, deflector plates between which the pencil or jet is passed, play the part of the conventional control grid, while where magnetic control action is relied upon, coils or loops of wire are made to play the part of the control grid in the electronic tube. Now, in order that the oscillation energy contained in the transversal oscillations of the pencil may be re-converted into current or voltage variations, or, in other words, in order to detach the said oscillation energy from the pencil, recourse may be had to several ways and means.

The simplest and oldest method is to cause the pencil to impinge upon two metallic collector or absorber electrodes rather than make it impact upon a fluorescent screen as in the oscillographic art, in such a fashion that, when in its quiescent state the pencil will just strike uniformly both electrodes or will pass through between them. As soon as the pencil is caused to deflect out of the said normal or quiescent position, the electronic current will flow over to either of the two collector or absorber electrodes or the anodes and the same is thus made available in the form of useful energy across any desired outside resistance or load, or be converted into voltages for further uses. It is true that at the present state of the art of electron optics, remarkably high current-voltage response and sensitiveness is obtainable, but the scheme proves a failure whenever very high frequencies are employed for the reason that at the joint between the two anodes, "blurring" or obliteration of the space-charges is occasioned, especially as a result of secondary electron production, and this tends to impair a clean and well-defined distribution of the current.

These drawbacks are avoidable if the oscillatory energy contained in the transversal oscillations of the electron pencil is separated from the kinetic motion energy of the electrons in the pencil. To this end the suggestion has been made to collect or impact the pencil upon an anode which does not carry high-frequency energy, with the result that the kinetic energy of the electrons is converted and dissipated thereon in the form of heat, while the transversal energy of the electron oscillations is detached or "uncoupled" from the anode by an electrostatic cross-field. Such a cross-field arrangement, for instance, may be built in such a way that the pencil a short distance ahead of its end, that is, at a point a small distance before it impacts upon the said anode, is made to traverse between two additional transversal plates so that these act as "anodes" properly so-called although they are not struck or impacted by the electrons contained in the jet. The "anode" currents which thus arise in the anode plates are displacement currents rather than convection currents, and they are produced by virtue of influence actions of the pencil charges oscillating between the "detachment" plates. If a high frequency potential is impressed upon the deflector plates, then high-frequency potentials of the same frequency may be obtained at the detachment plates, and the amplification, in the presence of unvarying frequency, is a function of the geometric ratio of the pencil lever, that is to say, the amplitude with which the electrons of the pencil oscillate through the detaching field. The voltages induced in the detachment plates may be fed back to the deflector plates properly so-called so that the scheme may be rendered self-oscillatory, pro-

vided that the phase balance is made positive by suitable disposition of the excited circuits and by convenient adjustment of the ultradynamic phase shift in the interior of the tube.

This arrangement whose efficiency and performance is unlimited even if the frequency is driven higher and higer, involves a certain difficulty, however, for while the tube is capable of furnishing appreciable no-load voltages, the inner resistance between the two detachment plates (which, as will be noted, is determined only by the displacement currents set up by the pencil charges) is comparatively high. As a result the tube is unable to deliver any appreciable energies at the anode end.

Now, this shortcoming is obviated by the present invention in that the high-frequency energy contained in the oscillating electron jet is uncoupled or detached by electromagnetic means rather than electrostatically, or, in other words, the detaching is insured by virtue of induction rather than influence actions. Hence, according to the invention, it is not the moved electrical field, but the magnetic field, whose force-lines surround the electronic pencil in the form of concentric rings, which furnishes the useful energy made available in the anode circuit.

Turning now to the drawing in which, Fig. 1 shows schematically one embodiment of my invention;

Figs. 2, 3 and 4 show modifications of the embodiment shown in Fig. 1 useful for the generation of ultra-high frequencies; and

Figs. 5 and 6 show further modifications of the embodiments shown in Fig. 1, while Fig. 7 shows a modification using electromagnetic deflection; the invention will be described n detail.

In order to describe more clearly the principle underlying the invention based upon a magnetic uncoupling action, the scheme shall be described in more detail by reference to Fig. 1 showing a semi-perspective view of the arrangement. The heated cathode K and a convenient electron-optic imaging system A_1, A_2 furnish a filamentary electron jet E. Shortly after its emergence from A_2, the pencil traverses the high-frequency transversal field set up by the control potential E_{st} impressed across the two plates P_1 and P_2 with the result that the pencil is deflected thereby in the plane of the drawing so that it reciprocates between the two limiting positions indicated by E_1 and E_2. At a little distance from P the pencil enters into the uncoupling or detachment coil S where it is caught on the anode A_3 mounted inside the said coil. In order to insure unimpeded entrance or penetration of the pencil into the coil, an aperture O is provided in the bottom face thereof. As the pencil experiences excursions or oscillations between the said two limiting positions E_1 and E_2, the left-hand and the right-hand longitudinally extending wires of coil S will be more or less enveloped by the magnetic force-lines which surround or shroud the pencil with the consequent result that voltages will be induced in the various conductors in accordance with the Biot-Savard law. Contradistinct to the above-described electrostatic uncoupling method, the inner resistance of the new arrangement here disclosed is very low, that is, equal to the ohmic and inductive resistance of the induction coil so that comparatively strong currents may be derived therefrom.

According to the law of induction, the induced potentials are a direct function of the variation of the magnetic force-lines cutting the various conductors per unit of time, in other words, if the pencil current is constant, the same is a function of the velocity at which the magnetic field moves in reference to the stationary conductors. In the presence of a given deflection amplitude, the said velocity, in turn, is directly proportional to the frequency. Under static conditions, that is to say, if the pencil is constantly deflected out of its normal or quiescent position by means of a D. C. potential applied to the plates P_1 and P_2, the tube will fail to work entirely, inversely, the voltages induced in S rise to so much higher values, the higher the working frequency of the tube.

In view of the extremely feeble magnetic fields which the electron pencil sets up around itself (whose current strength is of an order of magnitude of some milliamperes), the practical application of the new tube would primarily be inside the ultra-short-wave field that is to say, the very field in which standard tubes fail to operate for the reasons set forth in the preamble. However, this means that the tube in so far as its construction is concerned, should be designed so as to measure up to the requirements of this frequency spectrum. A multi-turn coil of the kind shown in Fig. 1 would be prohibitive completely because of its high inductance, in fact, it is imperative that the conductors disposed upon both sides of the electron pencil should be in the form of simple wire loops, and they should be connected together to form convenient useful circuits with due regard for the non-quasi-stationary distribution of current and potential.

An arrangement designed from the said viewpoint is shown, for instance, in Fig. 2. The electron pencil deflected in the control field P_1—P_2 impinges upon the anode A_3, while a short distance before this happens the pencil passes through between the two conductors S_1 and S_2, which, with interposition of two annular loops or clips L_1 and L_2 are united to result in a bilaterally short-circuited Lecher wire line of a length equal to $\lambda/2$ or multiples thereof. By the action of the currents induced along the length of the conductors S_1 and S_2 which constitute the short-circuiting bridge pieces of the Lecher-wire line, the latter is caused to oscillate so that a voltage loop (anti-node) is set up in the center thereof. From this point the HF energy, by the aid of an energy line coupled thereto may be fed to any desired consumer or load, or be fed back to the deflector plates P_1 and P_2 with a view to causing self-oscillation.

A simpler arrangement designed for inductive excitation of a Lecher-wire system is shown in Fig. 3. In this scheme the electron pencil is made to oscillate directly between the two wires L_1 and L_2 of the Lecher system, while being drained at the same time by the anode A_3 designed to form a terminal bridge. Fig. 4 shows in what way this arrangement may be designed to act as a regeneratively connected generator or oscillator by that the two Lecher wires L_1 and L_2 conjointly with the deflector plates P_1 and P_2 constitute an oscillable system by which the induced output potentials are re-used for deflection and control of the jet.

The phase relations of the feedback potential must be set in accordance with the ultra-dynamic phase shifts occurring in the tube. The same consist of an unvarying 90 degree component (or quadrature component) by which the induced currents are displaced in reference to the deflection potentials in the light of the law of in-

duction, and the phase angle which is due to the finite transit time of the electrons between the deflection field and the uncoupling coil. Inasmuch as it is here possible to choose at will the said ultradynamic phase angle by proper choice of the pencil velocity, that is to say, the anode potential, no definite outer feedback scheme is imposed, in fact, fundamentally speaking any desired organization in which the output potential with any desired phase at all is returned wholly or partly to the deflector plates, may be caused to become self-oscillatory as long as there results a positive balance of energy.

In Fig. 5 is finally shown an arrangement which, according to the invention, furnishes a frequency twice that with which the pencil is deflected. This scheme distinguishes itself from the arrangements before mentioned in that the induction conductors L_1 and L_2 are disposed outside rather than inside the plane of oscillation of the pencil, to be more precise, in such a way that the pencil when in quiescent state, passes through between them. Upon each excursion of the pencil towards the right and the left-hand side, and also upon the subsequent return to the quiescent position, positive and negative currents will be induced in the two conductors L_1 and L_2, that is to say, full periods are induced therein seeing that each time the conductors leave the magnetic field of force and re-enter into the same. If, then, the jet is subject to sinuous deflections, each deflection period will comprise two full periods of the induction current. If above and below the plane of oscillation of the electron pencil, several conductors spaced suitable distances apart are disposed, then, in lieu of simple frequency doubling, any desired frequency multiplication is obtainable. To describe this scheme more fully, reference is made to Fig. 6 in which the number of deflector plates is raised. The four induction rods or conductors are here connected together to result in two oscillation systems.

In the exemplified embodiments hereinabove disclosed, electrostatic pencil deflection by the aid of a transverse field set up between the plates P_1 and P_2 has been provided, but it will be understood that magnetic cross-control would fulfill the same purpose. In lieu of the sheets P_1 and P_2 there would have to be used in such a case wire loops similar to those previously suggested for inductive uncoupling. Preferably also the control circuit would then be given the form of a lecher-wire line whose short-circuiting bridges extend parallel to the pencil and cause deflection of the latter by the action of the surrounding magnetic field as shown in Fig. 7.

To produce control actions in the cross-field tubes here disclosed, either for regulation of the gain or for modulation purposes, action may be brought upon the oscillation mechanism at any desired point. The regulation or modulation of the anode potential is less advisable for the reason that the phase conditions are disturbed and affected by variations in the electron transit times, with the consequence that undesirable frequency fluctuations will be occasioned. A preferable plan is to regulate or control the intensity of the pencil current which is readily accomplishable by electron-optic means and ways, say, by the aid of a Wehnelt cylinder. However, the arrangements hereinbefore described allow a particularly simple solution of what may be called a mechanical modulation in that the electron pencil by means of a distinct deflector system acting at right angles to P_1 P_2 which is impressed with regulator or modulator potential is deflected out of its plane of oscillation. As a result the pencil is caused to recede from the induction wire, say, from L_1 and L_2, Fig. 4, and the magnetic field embracing the conductors and thus the production of oscillations becomes smaller.

Having described my invention, what I claim is:

1. The method of producing oscillatory electrical currents which comprises the steps of producing a beam of electrons, deflecting the beam of electrons, producing induction currents by the deflected beam of electrons, and utilizing a portion of the produced induction currents to deflect further the produced beam of electrons.

2. The method of producing oscillatory electrical currents which comprises the steps of producing a beam of electrons, deflecting the beam of electrons, producing induction currents by the deflected beam of electrons, and regeneratively deflecting further the beam of produced electrons by a portion of the produced induction currents.

3. The method of producing oscillatory electrical currents which comprises the steps of producing a beam of electrons, electrostatically deflecting the beam of electrons, producing induction currents by the deflected beam of electrons, and regeneratively deflecting further the beam of produced electrons by a portion of the produced induction currents.

4. The method of producing oscillatory electrical currents which comprises the steps of producing a beam of electrons, electromagnetically deflecting the beam of electrons, producing induction currents by the deflected beam of electrons, and regeneratively deflecting further the beam of produced electrons by a portion of the produced induction currents.

5. The method of producing electrically oscillatory currents which comprises the steps of producing a beam of electrons, deflecting the produced beam of electrons, producing induction currents by the deflected beam of electrons, and resonating a portion of the produced induction currents and regeneratively deflecting further the produced beam of electrons by the resonated portion of the produced induced currents.

6. The method of producing electrically oscillatory currents which comprises the steps of producing a beam of electrons, electrostatically deflecting the produced beam of electrons, producing induction currents by the deflected beam of electrons, and resonating a portion of the produced induction currents and regeneratively deflecting further the produced beam of electrons by the resonated portion of the produced induced currents.

7. The method of operating an electronic device which comprises producing a flow of electrons, focusing and accelerating the produced flow of electrons to produce a beam of electrons, deflecting the produced beam of electrons, producing induction currents by the deflected beam of electrons, regeneratively deflecting further the beam of electrons by a portion of the produced induction currents, and varying the acceleration of the electrons in accordance with modulating energy.

8. The method of operating an electronic device which comprises producing a flow of electrons, focusing and accelerating the produced flow of electrons to produce a beam of electrons, deflecting the produced beam of electrons, producing induction currents by the deflected beam of electrons, regeneratively deflecting further the beam of electrons by a portion of the produced induction currents, and varying the number of elec-

trons from the source in accordance with modulating energy.

9. An electronic system comprising means to produce a beam of electrons, means to deflect the beam of electrons, means to produce induction currents from the produced beam of electrons, and means to feed back a portion of the produced induction currents to the deflecting means to produce further deflection of the beam of electrons.

10. An electronic system comprising means to produce a beam of electrons, means to deflect the beam of electrons, means to produce induction currents from the produced beam of electrons, and transmission line means to feed back a portion of the produced induction currents to the deflecting means to produce further deflection of the beam of electrons.

11. An electronic system comprising means to produce a beam of electrons, means to deflect the beam of electrons, means to produce induction currents from the produced beam of electrons, and resonant line means to feed back a portion of the produced induction currents to the deflecting means to produce further deflection of the beam of electrons.

12. An electronic system comprising means to produce a beam of electrons, means to deflect the beam of electrons, means to produce induction currents from the produced beam of electrons, and short-circuited resonant line means to feed back a portion of the produced induction currents to the deflecting means to produce further deflection of the beam of electrons.

HANS E. HOLLMANN.